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Effects of Residual Fertility and Cowpea Residues on Succeeding Maize Growth and Yield in Ghana

Moses Ahmed Daramy[a]*, Joseph Sarkodie-Addo[b], Gibrilla Dumbuya[c]

[a,c]Sierra Leone Agricultural Research Institute/Rokupr Agricultural Research Centre, PMB 1313 Tower Hill Freetown Sierra Leone

[b]Department of Crop and Soil Sciences, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

[c]Sierra Leone Agricultural Research Institute/Njala Agricultural Research Centre, PMB 1313 Tower Hill Freetown Sierra Leone

[a]Email: daramymoses@gmail.com, [b]Email: jaddosak@yahoo.com, [c]Email: gibrildumbuya@gmail.com

Abstract

A field experiment was conducted at the Plantation Section of the Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology (KNUST), Ghana during the minor cropping season of 2014. The aim of the study was to evaluate the effect of residual nitrogen and phosphorus fertilizer and cowpea residues on the growth and yield of the succeeding maize crop in the semi-deciduous forest zone of Ghana. The experiment was a 5 × 4 factorial experiment with treatments arranged in a randomized complete block design with three replicates. The treatments were (i) residual 0, 10, 20, 30 and 40 kg N/ha in the preceding growing season combined with cowpea residues; and (ii) residual 0, 15, 30 and 45 kg/ha P_2O_5 combined with cowpea residues. Residual fertilization and the addition of cowpea residues did not significantly affect maize growth and yield indices. Plots that received only cowpea residues without residual fertilization produced similar yields as those that received N and P fertilizer in the preceding year. Thus cowpea residues alone without residual N and P fertilizer can support the growth and yield of the subsequent maize crop in the semi deciduous forest zone of Ghana. However, further studies are recommended to verify these findings.

Keywords: Maize; growth; yield; residual fertilizer; cowpea residues.

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* Corresponding author.

1. Introduction

Maize is the third most important cereal after wheat and rice in the world [1] and the most important cereal in most African countries including Ghana [2]. It is used as food for humans, feed for animals and raw material for industries [3]. Therefore, maize will play a significant role in the attainment of food security in both rural and urban communities. Despite the importance of the crop, the yields obtained by most farmers in Ghana are low - an average of 1.9 t/ha [4]. Low soil fertility and low application of external inputs are among the major factors accounting for the low productivity of maize. Soils in sub-Saharan Africa (SSA) are generally low in fertility, particularly nitrogen (N) and phosphorus (P) [5]. Consequently, there is a need for external nutrient supply to growing crops in these soils. Mineral fertilizer use is necessary for improving the growth and yield of crops [6]. However, farmer`s poor financial status is a limitation to the use of such fertilizers in SSA [7], hence the poor growth and low yield of crops prevail in this region. Research on sources of affordable nutrients for farmers in the region is imperative.Crop rotation that involves cereals and grain legumes has been recognized for improving cereal yields in tropical soils [8,9]. Grain legumes can ameliorate soil fertility decline and enrich soils with organic matter thereby improving the yield of the subsequent cereal crop [10,11,12]. Unfortunately, as a result of poor soil fertility with low levels of nitrogen and available phosphorus in SSA, the potential of legumes to grow well, their N-fixing (< 5 kg N/ha/yr) ability [13], and their effects on succeeding cereal crops is greatly hindered. Hence, there is a need for the application of mineral N and P fertilizer during the growth of legumes in order to improve their growth [14], biomass production [15], nutrient accumulation [15] and subsequent positive effects on succeeding cereal crops. Cereal crops like maize feed heavily on mineral fertilizers as compared to legumes. However, farmers in SSA cannot afford to apply such huge doses to satisfy cereal needs. Therefore, the application of small quantities of mineral fertilizer to legumes with the aim of boosting their growth, biomass production, N-fixation and nutrient accumulation in order to improve their effect on the growth and yield of the subsequent cereal crop will be worthwhile. An advantage of this practice will be the reduction of mineral fertilizer use during cereal cropping which will be economical and environmentally friendly. When mineral fertilizer is applied to legumes, the cereal crop planted on that same plot in the following season can benefit from the residual fertilizer and the incorporated legumes residues. Based on this, the study was conducted to evaluate the effect of residual nitrogen and phosphorus fertilizer and cowpea residues on the growth and yield of the succeeding maize crop in the semi-deciduous forest zone of Ghana.

2. Materials and Methods

The field study was conducted during the minor rainy season of 2014 at the plantation section of the Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana in the semi deciduous forest vegetation zone of Ghana (latitude 06° 43’N and longitude 01° 33’W). The experiment was a follow up to a previous experiment (a factorial experiment where in the treatments were arranged in a randomized complete block design and replicated three times) which was conducted during the major rainy season of 2014 on the same plots to evaluate cowpea response to nitrogen (0, 10, 20, 30 and 40 kg N/ha) and phosphorus (0, 15, 30 and 45 kg P_2O_5/ha) fertilizer application rates. After harvesting of the cowpea, all the cowpea residues were left on each plot. The plots were not tilled; three seeds of maize (variety Abontem) were planted on 8 September, 2014 at a depth of 4-5 cm deep and a spacing of 70 cm between rows and 30 cm between hills. Each of the 60 plots measured 4.1 m×1.9 m with 0.5 m between plots and 1 m between replications. The maize was thinned to two plants per hill at 14 days after planting (DAP) and the plots were weeded with a hoe at 35 DAP. Stem borers were controlled by applying sunpyrifos (Chlorpyrifos-methyl) at 50ml to 15 liters of water every 7 days.

Table 1 presents weather parameters during the experiment.

Table 1: Weather conditions during the experiment

Parameters	**Values**
Mean daily maximum temperature (^{0}C)	31.85
Mean daily minimum temperature (^{0}C)	22.34
Total rainfall (mm)	317.85
Relative humidity (%)	83.67 (09:00 hours GMT) to 59.17 (15:00 hours GMT)

[16]

Table 2 shows that the soil has a sandy loam texture and is low in fertility, mainly nitrogen, phosphorus and organic matter which are below the critical level reported by [17].

Table 2: Characteristics of the soil at the experimental site

Depth (cm)	0-15	15-30
pH	5.57	5.50
% Total nitrogen	0.15	0.12
Available phosphorus (mg/kg)	5.65	5.22
% Organic carbon	0.72	0.50
% Organic matter	1.24	0.86
Exchangeable bases (cmol kg^{-1})		
Potassium	0.16	0.09
Calcium	2.00	2.80
Sodium	0.38	0.37
Magnesium	1.00	0.80
% Sand	84.30	80.90
% Silt	3.90	4.07
% Clay	11.80	15.03
Soil texture	Sandy loam	Sandy loam

The biomass of five cowpea plants per plot were collected at harvest and analyzed for their nutrient contents (Table 3).

Five plants from the second row of each plot were selected randomly and tagged for the collection of growth data at 25, 45, and 65 DAP and yield data at harvest (75 DAP).

Plant height: This was measured from the ground level to the apical portion of the stem with a meter rule and the average height was calculated for each plot. Number of leaves: All leaves on the tagged plants were counted and the mean was calculated for each plot. Stem girth: Venier calipers were used to measure the stem girth at 2cm above soil level. The average stem girth per plot was recorded.Dry matter yield: Five plants per plot were selected randomly and cut at ground level, placed in different labeled envelops and oven-dried at 80^0C for 48 hours. Dry matter per plant was determined by weighing each sample and the average was computed for each plot.

Table 3: Nutrient contents of cowpea residues

Treatment	N (%)	P (%)	K (%)	C (%)	Ca (cmol/kg)	Mg (cmol/kg)	Na (%)
Control	1.30	0.31	1.09	44.95	0.32	0.50	0.23
N2	1.68	0.38	1.21	42.03	0.45	0.57	0.22
N3	1.21	0.48	1.02	43.36	0.40	0.54	0.21
N4	1.67	0.44	1.02	48.68	0.53	0.62	0.26
N5	1.51	0.46	1.39	47.08	0.52	0.63	0.29
P2	1.23	0.37	0.93	45.49	0.31	0.46	0.22
P3	1.33	0.37	1.00	42.56	0.47	0.56	0.22
P4	1.53	0.31	1.09	43.09	0.42	0.50	0.24
N2+P2	1.67	0.38	1.38	50.27	0.48	0.57	0.24
N2+P3	1.36	0.36	1.13	45.22	0.48	0.61	0.25
N2+P4	1.30	0.49	1.12	43.89	0.41	0.55	0.26
N3+P2	1.28	0.4	1.30	46.28	0.32	0.46	0.25
N3+P3	1.48	0.48	1.10	46.02	0.47	0.54	0.21
N3+P4	1.65	0.51	1.20	43.89	0.52	0.69	0.23
N4+P2	1.35	0.56	1.68	45.22	0.44	0.544	0.24
N4+P3	1.29	0.46	1.98	46.02	0.41	0.53	0.36
N4+P4	1.74	0.45	1.59	49.48	0.46	0.59	0.34
N5+P2	1.43	0.43	1.06	44.42	0.44	0.55	0.23
N5+P3	1.57	0.48	1.09	45.49	0.34	0.51	0.23
N5+P4	1.40	0.39	1.49	46.02	0.39	0.61	0.49

N_2= 10 kg/ha N; N_3= 20 kg/ha N; N_4= 30 kg/ha N; N_5= 40 kg/ha N; P_2= 15 kg/ha P_2O_5; P3= 30 kg/ha P_2O_5; P4= 45 kg/ha P_2O_5

Mean number of cobs per plant: At maturity, five plants were selected randomly from the border rows, their cobs were counted and the average number of cobs per plant was determined for each plot.

Number of grains per cob: Five cobs were selected at random from each plot. The number of grains in five rows on each cob was counted; the average was calculated and multiplied by the number of rows on the cob. The mean number of grains per cob for each plot was then computed.

1000-grain weight: One thousand grains were selected randomly for each plot, counted and weighed. This weight was recorded as 1000-grain weight for each plot.

Grain yield: Plants from the central net plot area of 2.10 m^2were harvested, the clean grains were weighed, and the weight was extrapolated from $g/m^2$to kg/ha.

Harvest Index: Five randomly selected plants in the border rows were cut at ground level, placed in labeled envelops and oven-dried at 80^oC to constant weight.

The harvest index was calculated using the formula of [18] and expressed as a percentage.

$$\text{Harvest Index} = \frac{\text{Economic yield}}{\text{Total biological yield (Above ground part)}} \times 100\ \%$$

Where economic yield is the grain yield of the five plants whilst the total biological yield is the summation of total biomass and seed yield plus cobs.

Analysis of variance (ANOVA) was performed for the collected data using GenStat 12^{th} edition statistical package. Least Significant Difference (LSD) at 5% was used to determine the significance of differences between means.

3. Results and discussion

Table 4 shows that maize growth parameters were not significantly affected ($P > 0.05$) by residual N combined with cowpea residues and residual P combined with cowpea residues at all the sampling periods.

Table 5 shows that maize dry matter yield was not significantly affected ($P > 0.05$) by residual N combined with cowpea residues nor with residual P combined with cowpea residues at all the sampling periods.

The effects of residual N and P fertilizer combined with cowpea residues on yield and yield components of the succeeding maize crop are presented in Table 6. The effects were not significant. The statistically similar maize growth and yield observed in our study for residual N and P fertilizer could be attributed to the fact that N is a highly mobile nutrient and can be lost through several processes. Therefore, the possibility for residual effect of such small doses of N to be seen on the succeeding maize crop is slim, while P, on the other hand, has the tendency to be fixed in the soil into forms unavailable for plant use by reacting with soil particles, Fe, Al, Ca and Mg.

Table 4: Effects of residual N, P and cowpea residues on the growth of the succeeding maize crop

	Plant height (cm)			**Number of leaves**			**Stem girth (cm)**		
Treatments	**25 DAP**	**45 DAP**	**65 DAP**	**25 DAP**	**45 DAP**	**65 DAP**	**25 DAP**	**45 DAP**	**65 DAP**
Residual N (kg/ha) plus residues									
Residual 0 N+ residues	75.87	167.80	225.10	7.47	9.52	10.80	0.76	1.47	1.62
Residual 10 N+ residues	80.98	175.70	230.30	7.53	10.22	11.13	0.81	1.51	1.71
Residual 20 N+ residues	79.72	168.60	226.80	7.68	9.78	10.38	0.74	1.46	1.61
Residual 30 N+ residues	78.80	173.50	229.70	7.73	10.02	10.88	0.80	1.54	1.65
Residual 40 N+ residues	76.09	165.60	225.80	7.53	9.83	10.97	0.74	1.44	1.69
LSD (5%)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Residual P (kg/ha) plus residues									
Residual 0 P_2O_5 + residues	76.17	166.30	225.50	7.40	9.83	10.99	0.71	1.47	1.65
Residual 15 P_2O_5+ residues	77.55	168.90	232.50	7.81	9.99	10.80	0.77	1.48	1.71
Residual 30 P_2O_5+ residues	79.66	169.80	222.60	7.55	9.95	10.83	0.78	1.45	1.60
Residual 45 P_2O_5+ residues	79.77	175.90	229.60	7.60	9.73	10.72	0.81	1.53	1.67
LSD (5%)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Residual N×P	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
CV (%)	**7.6**	**8.8**	**4.4**	**8.0**	**6.0**	**5.8**	**16.1**	**9.5**	**9.7**

DAP = Days after planting

Table 5: Effects of residual N, P and cowpea residues on shoot dry matter of the succeeding maize crop

	Shoot dry matter yield (g)		
Treatments	**25 DAP**	**45 DAP**	**65 DAP**
Residual N (kg/ha) plus residues			
Residual 0 N+ residues	2.79	28.98	59.80
Residual 10 N+ residues	3.63	34.73	72.00
Residual 20 N+ residues	3.02	30.12	56.90
Residual 30 N+ residues	3.01	30.46	64.10
Residual 40 N+ residues	2.75	31.44	62.90
LSD (5%)	**NS**	**NS**	**NS**
Residual P (kg/ha) plus residues			
Residual 0 P_2O_5 + residues	2.83	29.07	53.90
Residual 15 P_2O_5+ residues	3.09	32.63	66.10
Residual 30 P_2O_5+ residues	3.05	30.89	65.80
Residual 45 P_2O_5+ residues	3.19	32.00	66.80
LSD (5%)	**NS**	**NS**	**NS**
Residual N×P	**NS**	**NS**	**NS**
CV (%)	**24.9**	**21.0**	**23.0**

DAP = Days after planting

The result further reveals that all the plots that were expected to contain residual N and P from the previous season produced similar maize growth and yield with plots that did not received N and P fertilizer the previous year but had only the incorporated cowpea residues as means of fertilization. This indicates that the use of cowpea residues alone without residual N and P fertilizer can support the growth and yield of maize. Studies that have examined the effect of rotating cereals with legumes reported a positive effect on cereal yield following the incorporation of legume residues [8,9,19]. Reference [13] reported that the practice of recycling grain legume residues after harvest can provide net nitrogen as high as 140 kg N/ha depending on the legume.

Table 6: Effect of residual N and P combined with cowpea residues on yield and yield components of the succeeding maize crop

Treatment	No. of cobs plant^{-1}	No. of seeds cob^{-1}	1000 grain weight (g)	Harvest index (%)	grain yield (kg/ha)
Residual N (kg/ha) plus residues					
Residual 0 N+ residues	1.06	377.70	174.80	43.48	2505.00
Residual 10 N+ residues	1.08	381.70	167.00	44.10	2733.00
Residual 20 N+ residues	1.08	371.40	167.80	45.35	2667.00
Residual 30 N+ residues	1.05	368.80	173.50	43.82	2714.00
Residual 40 N+ residues	1.05	355.20	184.00	44.20	2562.00
LSD (5%)	**NS**	**NS**	**NS**	**NS**	**NS**
Residual P (kg/ha) plus residues					
Residual 0 P_2O_5 + residues	1.02	369.20	165.50	42.01	2351.00
Residual 15 P_2O_5 + residues	1.02	379.80	173.50	44.86	2760.00
Residual 30 P_2O_5 + residues	1.13	354.70	176.50	45.42	2521.00
Residual 45 P_2O_5 + residues	1.08	380.20	178.20	44.46	2913.00
LSD (5%)	**NS**	**NS**	**NS**	**NS**	**NS**
Residual N×P	**NS**	**NS**	**NS**	**NS**	**NS**
CV (%)	**11.8**	**18.6**	**9.4**	**10.0**	**25.5**

5. Conclusion

The study revealed that the yield of maize was the same when cowpea residues alone from a previous cowpea crop was incorporated as when the cowpea residues were combined with residual N and P fertilizer from the previous season.

6. Recommendations

In the semi deciduous forest zone of Ghana, low soil fertility is a factor accounting for the low yields of most crops and the purchase of mineral fertilizer is constrained by the poor financial status of farmers. Based on the results of this study, it is recommended that cowpea residues be incorporated into the soil for the benefit of the subsequent maize crop. However, further studies are recommended to verify the findings of this study.

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